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NOTES AND LITERATURE

LINKAGE IN THE SILKWORM MOTH

ONE of the most striking recent developments in the study of genetics is the discovery of linkage in many of those forms which were supposedly thoroughly worked out. The most recent example is a very interesting paper by Y. Tanaka,¹ entitled "Gametic Coupling and Repulsion in Silkworms." The data presented in this paper demonstrate the existence in the silkworm moth of a group of four pairs of linked genes. Following Tanaka's nomenclature we may designate these genes as follows: *N*, which differentiates the larval color pattern known as "normal" from that called "plain"; *S*, occurring in larvae having the "striped" pattern, and epistatic to *N*; *M*, the differentiator for the "moricaud" larval pattern, also epistatic to *N*; *Y*, the gene which differentiates caterpillars with yellow blood and yellow cocoons from the recessive whites. Of the six possible combinations of these genes, taken two at a time, all but *NM* and *SM* were made, and all showed linkage. F_2 "coupling" tests, *i. e.*, from matings where both dominants entered the cross from the same P_1 individual, were made for *SY* and for *MY*. In each case there occurred cross-overs, or new combinations of the characters, in such proportions as to lead Tanaka to suppose the ratio of parental combinations to cross-overs among the gametes to be about as 7:1. "Repulsion" (where one dominant entered from each P_1 individual) F_2 results were obtained for *NS* and for *NY*. In neither case did any double recessives (cross-overs) appear, though over 3,000 caterpillars were obtained in the case of *NY*, and 224 in the case of *NS*. From these data Tanaka concludes that the repulsion was complete in these two cases. It has, however, been pointed out by Morgan² that such results will be obtained if the linkage is complete in one sex only. In *Drosophila* such "repulsion" crosses never produce double recessives in F_2 , and it has been shown that this is due to complete linkage in the male, crossing over being frequent in the female between some pairs of genes. In order to test this possibility it is necessary to mate doubly heterozygous individuals to double recessives, when the gametic ratio is obtained directly and without the complications present in most F_2 results. It so happens that Tanaka reports two such crosses, one for each sex, though he does not recognize their im-

¹ *Jour. Coll. Agr.*, Tohoku Imper. Univ., Sapporo, Japan, V, 1913.

² *Science*, N. S., XXXVI, 1912.

portance in this connection. When a male heterozygous for *S* and for *Y*, one dominant having been derived from each parent (*SysY*), was mated to a doubly recessive (*sysy*) female, there were produced 63 *Sy* and 65 *sY*—no cross-overs. A female heterozygous also for *S* and for *Y*, but having them “coupled” (*SYsy*), was mated to a male *sysy*, and produced 215 *SY* and 188 *sy*—again no cross-overs. Yet that crossing over may occur between these two pairs of genes is shown by the fact that the “coupling” F_2 results indicated a gametic ratio of about 7:1:1:7. We are, therefore, still left in the dark as to whether crossing over occurs in only one sex, or in both. But it is certain that the strength of linkage in this case is not always the same—a point of great interest and importance. Similar cases have been reported by Baur³ in *Antirrhinum*, by Punnett⁴ in the sweet pea, and by the writer⁵ in *Drosophila*.

Tanaka refers to his case as differing from previously reported cases of linkage in animals in that the sex differentiator is not one of the genes involved, and in that the linkage is sometimes only partial. However, he refers several times to a paper by Morgan⁶ in which it is clearly shown that three of the sex-linked genes in *Drosophila* also show partial linkage to each other, independently of their sex-linkage. Punnett,⁷ in referring to the same paper, has said, “Morgan’s experiments with *Drosophila* suggest coupling of some kind between factors for eye color and shape of wing, though both of these factors may show sex-limited inheritance in other families.” A study of the data referred to, or of any of the similar data on *Drosophila* since published, will show that these genes *always* show sex-linkage, and that *at the same time* they always show linkage to each other when both can be followed in the analysis. The two phenomena are not mutually exclusive, but both are always present.

Both Tanaka (in a footnote) and Punnett refer to the latter’s case in rabbits as the first example of linkage in animals not involving sex. If the linkage between sex-linked genes is, for some strange reason, not considered to belong in this category, there are still at least two cases which antedate Punnett’s slightly. A few months before Punnett’s paper appeared I had suggested⁸ the possibility of linkage in mice. It now seems rather probable that the relation in both mice and rabbits may really be that of

³ *Zeits. f. ind. Abst.-u. Vererb.-Lehre.*, VI, 1912.

⁴ *Jour. Genet.*, III, 1913.

⁵ *Science*, N. S., XXXVII, 1913.

⁶ *Jour. Exp. Zool.*, XI, 1911.

⁷ *Jour. Genet.*, II, 1912 (Nov.).

⁸ *AMER. NAT.*, XLVI, 1912 (June).

triple allelomorphism. For this reason I am inclined to assign priority to Morgan and Lynch,⁹ whose paper on linkage of genes in *Drosophila* which are not sex-linked appeared after my own paper and before Punnett's.

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NABOURS'S BREEDING EXPERIMENTS WITH GRASSHOPPERS

IN a recent paper, Nabours ('14) describes breeding experiments that he has been carrying on for some years with grouse locusts of the genus *Paratettix*. His work is of special interest in showing that in a wild species there exists a number of distinct types that show alternative inheritance of a particular kind. His paper may be summarized as follows:

1. Nine distinct, true breeding forms of *Paratettix* were collected "in nature." These "species" (as Nabours is inclined to consider them) "are mainly distinguished by their striking color patterns."

2. When an individual of one of these species is mated to one of a different species the hybrid character of the offspring is apparent at once, in that "all the characters of each parent are represented in the F_1 hybrid." In other words, the hybrid is in a certain sense an intermediate, and "the terms dominant and recessive" are probably not "applicable at all." This point, while of little theoretic importance, has a practical value in that the zygotic constitution of any hybrid can be recognized without further breeding tests.

3. With one exception, each color pattern factor was found to behave as an allelomorph to any other color pattern factor.

4. The various lengths of the wings and pronotum are apparently not inherited, as such but are determined by environmental factors, especially such as tend to prolong or to shorten the length of larval life.

It appears that Nabours confuses the relation of the facts mentioned under 3, and that he supposes this to be the ordinary behavior of "mendelizing characters," for he says:

The essential result of these experiments has been the extension of this principle [Mendelian inheritance] to a considerable number of types of a phylogenetically low group of ametabolous insects.

To be sure, he recognizes that other workers in genetics have an attitude quite different from his, and he takes some little pains to make clear his own point of view. To quote again (p. 142):

⁹ *Biol. Bull.*, XXIII, 1912 (Aug.).